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COMPUTER VISUAL SIMULATION OF CONTRAST SENSITIVITY DEFICITS INDUCED BY LASER AND CHEMICAL ANTIDOTE EXPOSURE

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(Signature and date)

Computer Visual Simulation of Contrast Sensitivity Deficits Induced by Laser and Chemical Antidote Exposure

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SUMMARY

Effective training of a complex combat-related task presently requires training that may produce a transient degree of visual impairment. The present paper presents an alternative method, i.e., simulating visual impairment produced by potential combat conditions. The degree of realism provided by such simulation offers development of safer as well as more realistic training techniques.

The ability to represent a complex visual image along a unitary dimension and relate this dimension to target acquisition criteria is critical to military training concepts. Recent experiments have suggested that the physics of form and human spatial vision are uniquely related to the spatial frequency domain (1). Small changes in the amplitude of selective spatial frequenies can have significant effects on human form vision (2).

A scheme to represent a complex target along a single, spatial frequency continuum was first proposed by Johnson (3). The Johnson criterion relates the number of cycles in a square wave grating (black bars periodically alternating with white bars) required for either detection, identification, or recognition, to complex military targets as a function of target range. Complex military targets can be scaled with respect to the number of cycles required for either detection, identification, or recognition.

While the Johnson criterion is adequate for scaling high contrast stimuli in a reliable manner, it is neither parsimonius with current physiological mechanisms underlying human spatial vision nor adaptable to characterizing how the perception of complex images might be degraded by exposure to noxious battlefield conditions.

Many recent experiments reporting such effects indicate that mechanisms underlying spatial vision are selectively altered with regard to their ability to represent the spatial frequency domain. Such degradation in the neural mechanism of spatial vision is not easily represented by changes in the number of cycles required for a visual response.

Image degradation that might be produced by potential battlefield exposure conditions can be simulated by modulating the spatial frequency content of a complex image in accordance with the actual amplitude modulation induced by experimental procedures. In this paper, spatial frequency contributions have been modified according to the results of experimental data, to obtain the inverse fourier transform of a complex mage.

METHODS

A computer interfaced with a video frame buffer was used to produce fourier filtered images. The frame buffer used stored images in a 256 by 256 pixel format with 64 shades of grey (4). A two-dimensional fast fourier transform (FFT) was used to alter the spatial frequency content of a complex image in accordance with changes that had been induced in contrast sensitivity experiments. The original image was filtered by reducing the signal amplitude contributions at selected spatial frequencies in direct proportion to losses obtained in contrast sensitivity at corresponding spatial frequency points. An inverse FFT was then performed and the filtered image displayed on a CRT and stored on hard disk.

Data from three contrast sensitivity experiments were used. The acute effects of Q-switched pulsed laser exposure(5), benactazine (6), and atropine (7) on contrast sensitivity were used to obtain degraded images in correspondence with previously obtained contrast sensitivity data.

RESULTS

Contrast sensitivity data, replotted as a percentage of the baseline contrast sensitivity for acute laser exposure (5) and for benactazine (6) are shown in Figure 1. Changes induced by atropine (7) were very slight, varying between 95 and 98% of baseline contrast sensitivity measured over the same spatial frequency range as used for benactazine.

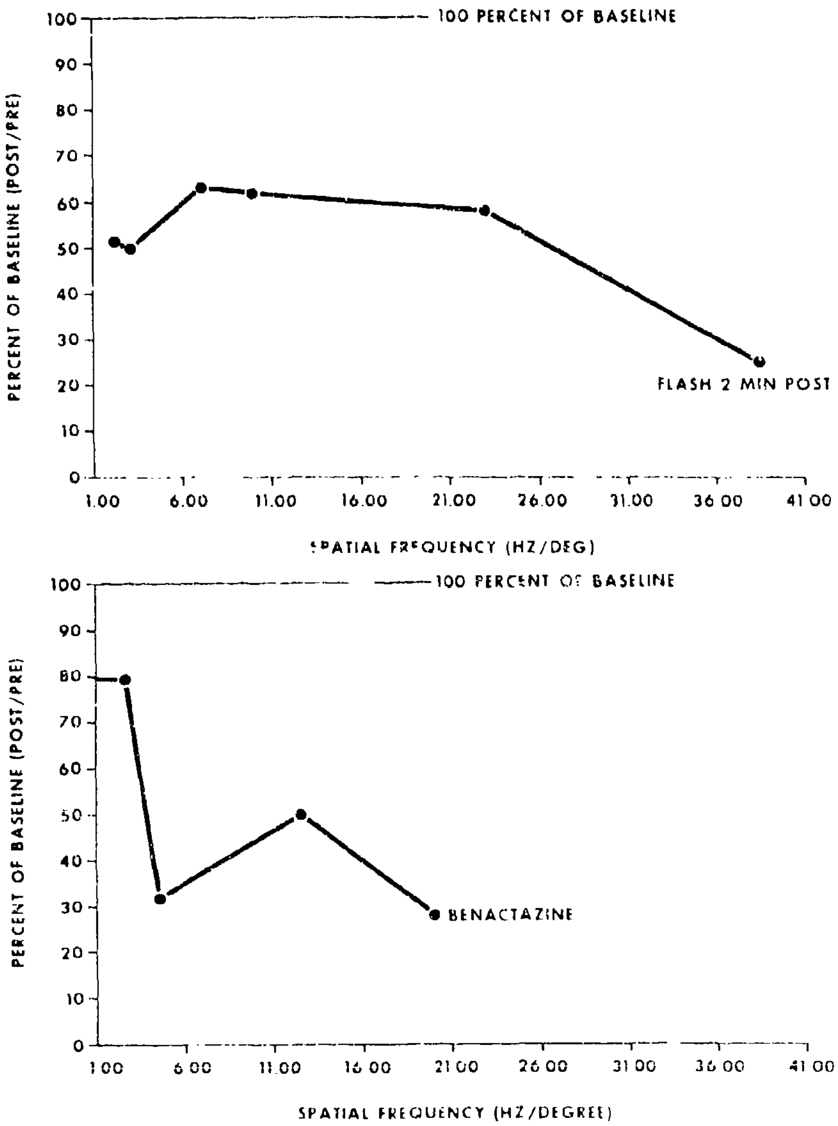

FIGURE 1. Contrast sensitivity functions from laser flash and benactazine (5,6) experiments replotted to reflect loss in contrast sensitivity over the spatial frequency spectrum relative to baseline contrast sensitivity.

Inverse transformed images based on the data from each of these experiments are shown in Figure 2a,b,c,d. The upper left panel is the normal digitized image(2a). In the upper right panel the image has been transformed according to changes induced by acute laser exposure measured at 2 minutes post-exposure. The lower left and right hand panels (c and d) correspond to the benactazine and atropine measured contrast sensitivity changes.

Because the effect of acute laser exposure is nearly uniform over the measured spatial frequency region, the image (b) appears to be reduced in overall contrast, unlike that of the same image transformed for the benactazine deficit (c). In this case, a definite blurring of the image is perceived, as fine spatial frequency loss is relatively greater than losses at the lower spatial frequencies. Minimal change in the perceived image qualities is observed for the atropine (d) condition.

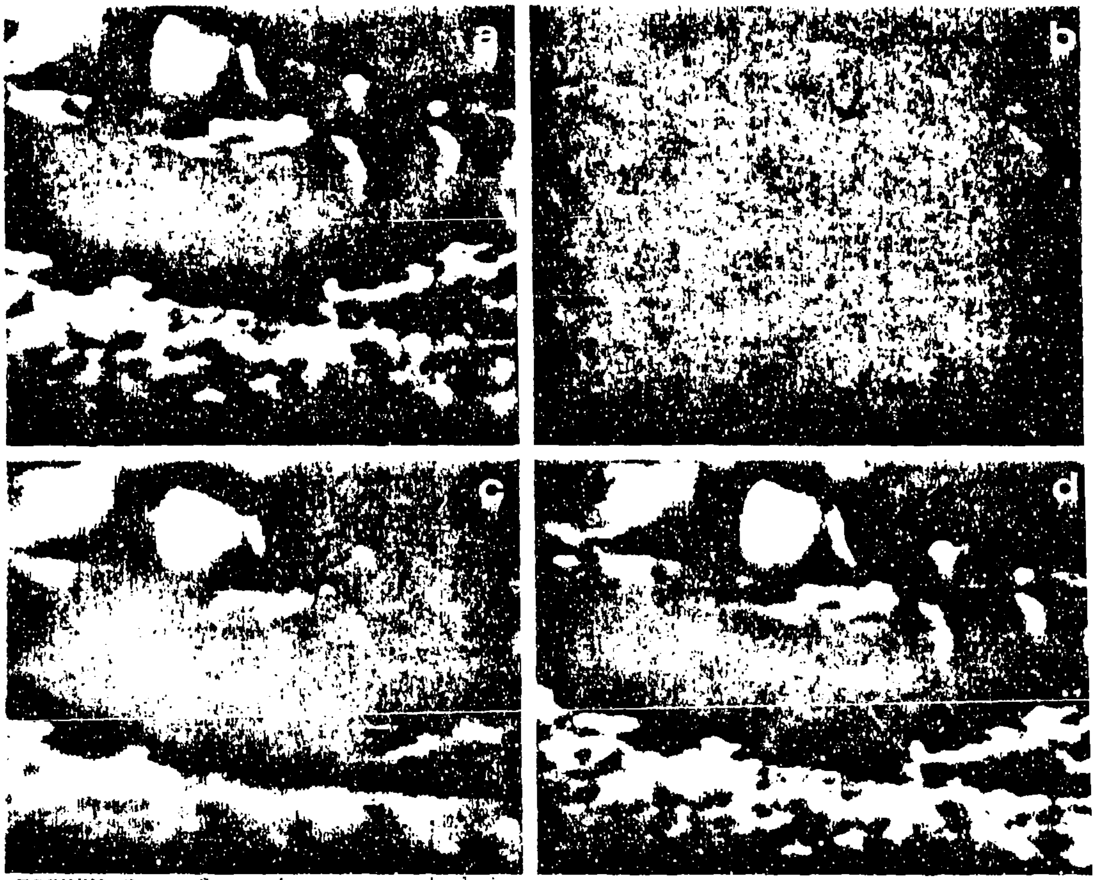

FIGURE 2. Computer generated images.

DISCUSSION

In this paper, we have demonstrated that contrast sensitivity data can be utilized to create degraded images that correspond to the measured changes obtained in spatial vision experiments. With this procedure, complex images can be modified to reflect the visual systems measured response to various noxious environmental conditions. More importantly, with such procedures, any image that can be digitized, can be modified and used in specific training scenarios. This method extends our ability to characterize complex stimuli by allowing both normal high contrast as well as degraded images to be represented along the spatial frequency dimension. The knowledge that certain exposure conditions might blur vision while others might simply alter the overall contrast of a complex scene is information that could only safely be provided with the aid of the present technique for characterizing the effects of noxious environmental conditions on spatial vision.

Finally, for the development of effective combat training, incorporation of the degradation technique provided here offers a viable and safer alternative to training procedures requiring adverse environmental conditions capable of producing moderate transient physiological effects.

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Training in some complex combat-related tasks may produce a degree of transient visual impairment which may simulate what could be expected in combat. This paper presents a method for simulating visual impairment produced by potential combat conditions. The use of a computer to both digitize and store as well as produce the simulated image has provided an ideal tool for research. The degree of realism provided by such simulation offers suggestions for development of more realistic training techniques.

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